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ANALYSIS OF THE SENSITIVITY OF THE HYDROMORPHOLOGICAL INDEX OF DIVERSITY, HMID

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ABSTRACT

Hydromorphological conditions are a key factor for the habitat diversity in riverine ecosystems. The Hydromorphological Index of Diversity (HMID) is a tool to quantify the habitat diversity in a river reach based on local flow depths and flow velocities. The work presented here analyzes the sensitivity of the HMID value towards input data. Since the evolution of the HMID, values of most of the 12 analyzed reaches arrive at a saturation value, after which the HMID value does not change anymore with additional data. This indicates that an over-sampling took place and a sub-sampling can be applied. Thereby, 50%, respectively 66%, of the input data were removed for the HMID computation. Results show that more measurement points are needed for reaches with a high geomorphological diversity in order to compute a representative HMID value than for reaches with uniform conditions.

Keywords: Morphology, River restoration, Index, HMID, Habitat diversity, Sensitivity analysis

1. INTRODUCTION

Water and sediment supply are key drivers in riverine ecosystems (Wohl et al., 2015). Riverine ecosystems host a large variety of habitats (Allan and Castillo, 2007) and are of high value due to their dynamics and the exchange between hydraulic and terrestrial habitats. Hydromorphological conditions are an essential factor for in-river life and species have their preferred flow conditions of flow depths, velocities and shear stresses near the stream-bed (Statzner et al., 1988). Jowett (1993) brought up an objective method to classify hydraulic habitats such as pool, riffle and run habitats in a river reach based on flow depth and velocity. Gostner et al. (2013a) and Lamouroux et al. (1995) were interested in the statistical properties of hydromorphological variables in rivers, while developing models for the prediction of habitat quality.

The Hydromorphological Index of Diversity (HMID) is a quantitative measurement tool for the habitat diversity in rivers, which combines the statistics of geomorphological and hydraulic conditions (Gostner et al., 2013b). The basic HMID of a river reach is defined in [1] and takes into account the spatial distribution (σ) of the hydraulic variables as flow depth (h) and flow velocity (v) measured in a certain river reach and computes a single value that represents the potential habitat diversity in the river reach. The HMID was elaborated in order to evaluate the habitat richness in rivers and combined with numerical models it has predictive power to quantify the effect of river restoration measures. Further, it can be used as control of success of a restoration measure.

$$HMID = \prod_i (1 + CV_i)^2 = \left(1 + \frac{\sigma_h}{\mu_h}\right)^2 \cdot \left(1 + \frac{\sigma_v}{\mu_v}\right)^2 \qquad [1]$$

where,

CV = coefficient of variation [-]
μ = mean value [m] or [m/s]
σ = standard deviation [m] or [m/s]

According to the resulting value, which usually is between 1 and 15, a river reach then can be assigned to a class. An HMID value below five indicates a heavily altered and channelized reach with uniform cross-sections and minor geomorphic patches. A reference site with fully developed spatial dynamics and a full range of hydraulic habitats has an HMID value larger than nine. Reaches with a limited variability have an HMID between five and nine. The computation and interpretation of the HMID are objective. However, the planning of measurement campaigns in the field have a wide range of uncertainties.

Analyses at 12 sample reaches in three rivers with different morphologies pointed out that oversampling happens often and how the sampling procedure can more efficient.

2. METHODOLOGY

Measurements of flow depth and velocity at 60% of the depth were taken along cross-sections. A distance of 1 m was applied between measurement locations. The distance between cross-sections varied, but was constant within a reach of analysis.

First, the development of the HMID value with every added measurement point was plotted for each of the 12 reaches. With this evolution of the HMID, information of data sufficiency for an HMID computation in each reach was gained.

Then, a sub-sampling in the transversal direction was applied. Here, the data from every second measurement point was excluded from the analysis (doubling of the distances). In a second step, every second and third measurement were removed, resulting in a data sample about 33% of the initial sample size (tripling of the distances). The aim of these sub-sampling procedures was to test how the sampling procedure could be more efficient.

Three rivers were subject in this analysis. The Venoge is a lowland river in the western part of Switzerland. It is about 40 km long with a mean annual discharge of 4.3 m^3/s at the mouth where it drains into the lake of Geneva. In the Venoge, four reaches were investigated: A meandering reach (Venoge I), two straight and channelized trapezoidal reaches (Venoge II & III) and a reach with alternate bars (Venoge IV). The Buenz is another lowland river in the northern part of Switzerland close to Zurich, with a mean annual discharge of 1.2 m^3/s. Surrounded by agricultural land, the Buenz is basically a straight channelized river. The first reach (Buenz I) is a restored site where the rip-rap protection of the banks was removed and logs and cobbles were added. Buenz II is a straight channelized reach. Approaching the mouth with the Aare, the Buenz follows its natural meandering patterns. The reach Buenz III is a 90° meander bend and Buenz IV is a braided reach where the river divides into two channels. The 42-km long Passer on the other hand is a steeper mountain river in South Tyrol, in north-western Italy. Flowing through a narrow valley, the Passer has been subject to river training for many decades and has a mean annual discharge of 5.7 m^3/s. Passer I is a reach where the river was widened locally and two alternate bars formed. Passer II is a channelized reach with a slight right-bend and a long gravel bar at the inner bank. The reach Passer III is a restored reach where the river was widened and a braided reach evolved. A stereotypical mountain river is seen in the reach Passer IV. Here, the Passer consists of a cascade of lateral sills that induce various different hydraulic conditions.

3. RESULTS

3.1 HMID evolution

The HMID value varies a lot with a small number of measurement points, and the more data points are added to the analysis, the more the HMID value becomes constant. The HMID value evolution reveals that most of the HMID values approach a more or less stable saturation value (Fig. 1). This is obvious for the reaches Venoge II, III & IV, Buenz I & II and Passer I, III & IV. The Venoge IV approaches its HMID value slowly, the channelized Venoge II & III reach a constant value already with 25 measurement points. The HMID value of Venoge I follows a repeating pattern with two local maxima. The Buenz is more interesting. The HMID of the Buenz I reaches a constant value just at the end of the sample measures, where Buenz II is constant already with 20 measurements. Buenz III, on the other hand, approaches slowly towards a value similar to the Venoge IV. However, with this graphic alone, it cannot be said, if it really reaches a constant HMID value. The HMID value of the Buenz IV peaks with 150 measurements and descends slowly towards the use of all measurements.

3.2 Effect of measurement points in a cross-section

The reaches behave differently if the distance between the measurement points is enhanced (Tab. 1). With a doubled distance, the HMID value of the majority of reaches does not differ more than 10% from the original value. The Venoge III & IV, Buenz II and Passer III reaches exceed this 10% margin. The Venoge III & IV as well as Buenz II have a relatively low HMID value, while Passer III has one of the highest values in the study.

If the distance between measurement points is tripled, the Venoge I & II, Buenz IV and Passer II are added to the reaches that differ more than 10% from the original value. In this case, HMID values from 8 out of 12 reaches differ more than 10% from their original HMID values, among them all reaches in the Venoge river.

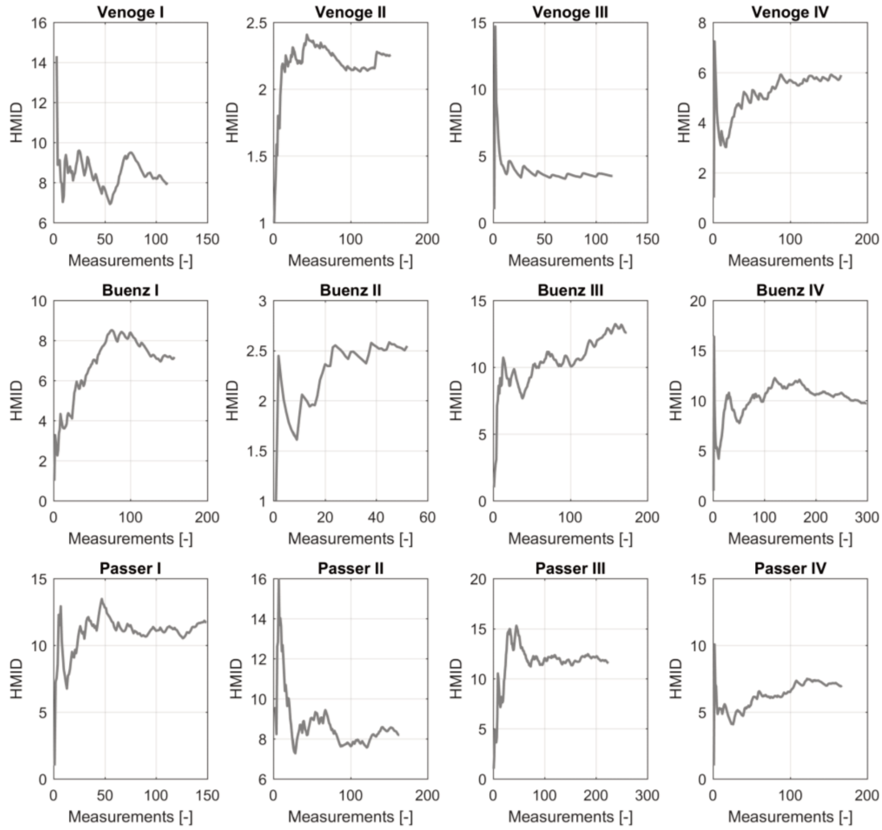

Figure 1. Evolution of the HMIDs at reaches in the Venoge, Buenz and Passer rivers. A trend towards a saturation value, after which the HMID does not change anymore with additional flow depth and flow velocity measurements, is observed at many reaches.

Table 1. Results of sub-sampling with increased distances between the measurement points in the cross-sections. HMID_0.5 means that the distance between the measurement points were doubled and only 50% of the data points were used for the analysis, analog with HMID_0.33 (33%). In the Δ colon, the differences compared to the HMID value calculated with the full sample are given in percentage. In the # colon, the number of measurement points for the corresponding analysis are given.

River name	Geomorphology	HMID [-]	HMID_0.5 [-]	HMID_0.33 [-]	HMID_0.25 [-]	Δ 0.5	Δ 0.33	# initial	# 0.5	# 0.33
Venoge I	meandering	8.01	8.11	10.2	9.08	-1%	-28%	111	56	37
Venoge II	channelized	2.26	2.35	2.60	2.31	-4%	-15%	152	76	51
Venoge III	channelized	3.50	4.19	4.50	5.11	-20%	-29%	116	58	39
Venoge IV	alternate bars	5.89	6.72	6.86	8.04	-14%	-16%	166	83	55
Buenz I	restored	7.18	7.74	7.86	7.82	-8%	-10%	157	79	52
Buenz II	channelized	2.55	2.90	3.32	2.97	-14%	-30%	52	26	17
Buenz III	meandering	12.6	13.1	13.5	13.7	-4.0%	-6.9%	173	87	58
Buenz IV	braided	9.76	9.65	11.6	10.9	1.1%	-19%	298	149	99
Passer I	alternate bars	11.7	12.2	12.6	14.2	-3.9%	-7.4%	149	75	50
Passer II	channelized	8.21	8.27	9.29	8.61	-0.7%	-13%	163	82	54
Passer III	braided	11.5	13.2	11.4	14.8	-14%	1.1%	224	112	75
Passer IV	straight, sills	6.99	6.38	7.69	7.07	8.8%	-10%	167	84	56

4. DISCUSSION & CONCLUSIONS

The repetitive pattern in the HMID evolution in the Venoge I (Fig. 1) may be explained by the repetitive pattern found in river geomorphology. While the Venoge I is a 90° river bend, the succession of riffles and pools may be repeated after a 45° bend. The generally higher HMID values in the reaches of the Passer compared to the Buenz and Venoge represent a difference between mountainous and lowland rivers. Where mountainous rivers are steeper, the flow results in shallower water depths and sediment of larger size is transported. This leads to a higher presence of macro-roughness elements that create local turbulences and therefore a larger diversity in hydraulic conditions.

The Venoge III & IV reaches together with the Buenz II are the most sensitive in the transversal sub-sampling analysis (Tab. 1). All reaches have a relatively low HMID value and therefore their relative difference compared to the original HMID value is higher. Looking at both sub-samplings, data from the Venoge are the most sensitive to removal of measurements than the data from the other rivers. This may be due to the number of measurements in the analysis. The Venoge reaches have the lowest average number of 136 measurement points. For the other reaches, there were 173 measurement points on average (170 Buenz, 176 Passer). An extreme case is the Buenz II, which only has 55 measurements. This is the lowest amount of measurement points of all analyzed reaches and explains its sensitivity towards the removal of measurement points.

In conclusion, the HMID trend reaches a clear saturation value in 7 of the 12 reaches (Venoge II, Venoge III, Venoge IV, Buenz II, Passer I, Passer III and Passer IV). Reaches with a higher geomorphological diversity (Venoge I, Buenz II) and restored sites (Buenz I and Passer II) have more local variability. Thus, their HMID trend varies in a kind of bandwidth once it stabilizes from the strong initial fluctuation. Reaches with a high diversified geomorphology (Buenz IV, Passer III) require a larger amount of data points than reaches with a homogenous geomorphology (Venoge I & II). Analyses at additional reaches and a comparison of reach length and the number of cross-sections may provide additional knowledge to determine user guidance about data sufficiency for the HMID computation.

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